GPM International Planning Workshop 2006.11.6-8

Multi-Sensor Precipitation Analysis Development in Japan

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Global Satellite Mapping of Precipitation (GSMaP) Project

GSMaP Project

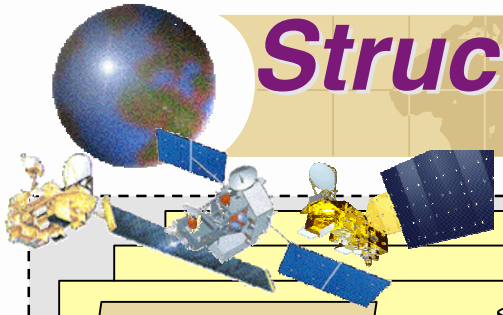
- This project started in 2002 under JST/CREST* (- Nov. 2007) program. One of the purpose of this project is to prepare the multi-sensor precipitation products in GPM era.
- 25 members, lead by Prof. Ken'ichi Okamoto (Osaka Prefecture Univ.)

Goals of the Research

- Production of high precision and high resolution global precipitation map by using satellite-borne sensors.
  - Microwave radiometers (MWRs, e.g. TMI, AMSR-E, SSM/I×3)
  - Precipitation radar, GEO's visible and IR radiometers
  - Target spatial resolution: 0.1º×0.1º, temporal resolution:1 day (MWRs) and 1 hour (MWR-IR combined)
- Development of reliable microwave radiometer algorithm
  - Based on the common physical precipitation model with precipitation radar.

**Core Research for Environmental Science and Technology sponsored by Japan Science and Technology Agency*

Structure of GSMaP Project



Algorithm Gr.

MWR Obs. Data

Look-up Table

Precipitation Retrieval

Physical Precip. Model Gr.

Ground Radar Observation Gr.

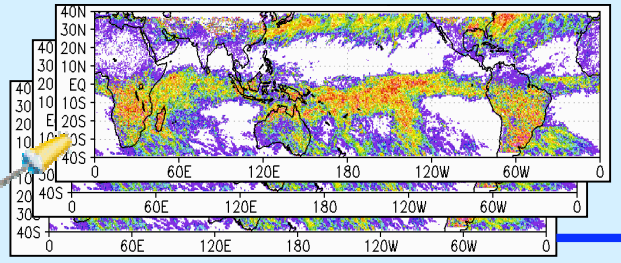
Routine Obs. Campaign Obs. Database

MWR products

feed back

validation

Global Precipitation Map



Precipitation Map Products

High Temporal Resolution Map

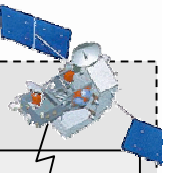
Geo-IR data (MTSAT, GOES, MSG)

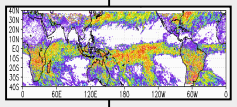
MWR+IR algorithm

Global Precip. Map Gr.

comparison

TRMM/PR





Obs. Data

Precip. Database

Radar Algorithm

GSMaP algorithms
Improvements and development

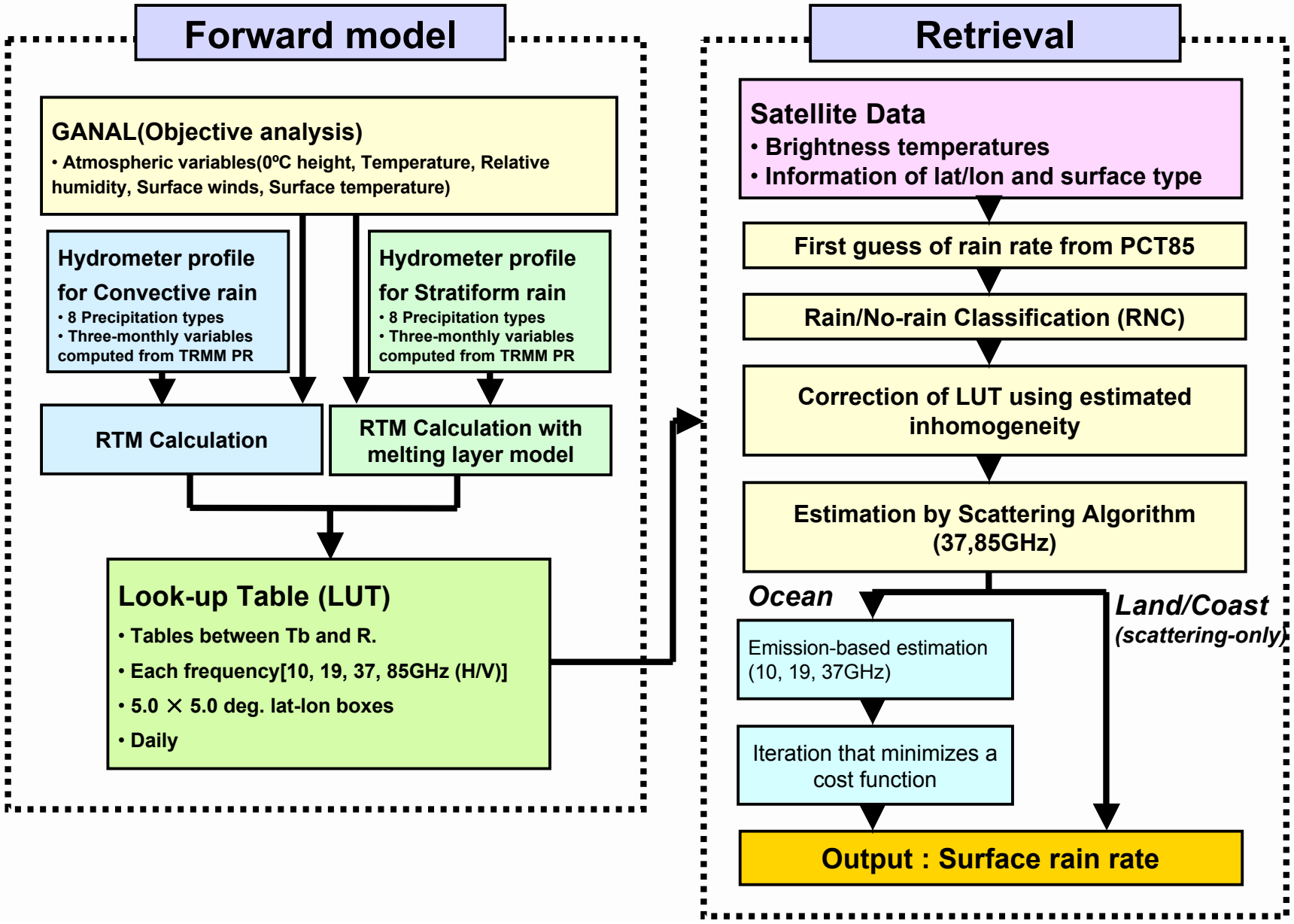
- MWR (Microwave Radiometer) algorithm

  Upgrade the algorithm developed by Aonashi and Liu (2000).
  - Scattering algorithm --- dual frequency method
  - Rain/No-rain classification algorithm over land --- use of PR-TMI statistics
  - Precipitation profile model --- rain type classification & PR's rain profile
  - Melting layer model --- same as TRMM/PR
  - Rain drop size distribution model --- based on the PR's DSD parameter
  - *Snow particle model --- under consideration*

  Applied to
  - TMI, AMSR, AMSR-E, and SSM/I
- MWR+IR combined algorithm for high temporal resolution map

  Use of IR-based motion vector to advect the rain area of MWR product.
  - Motion vector from Geo-IR data
  - Motion vector + rain estimation with Kalman filter
  - Forward and backward retrieval as post-processing product

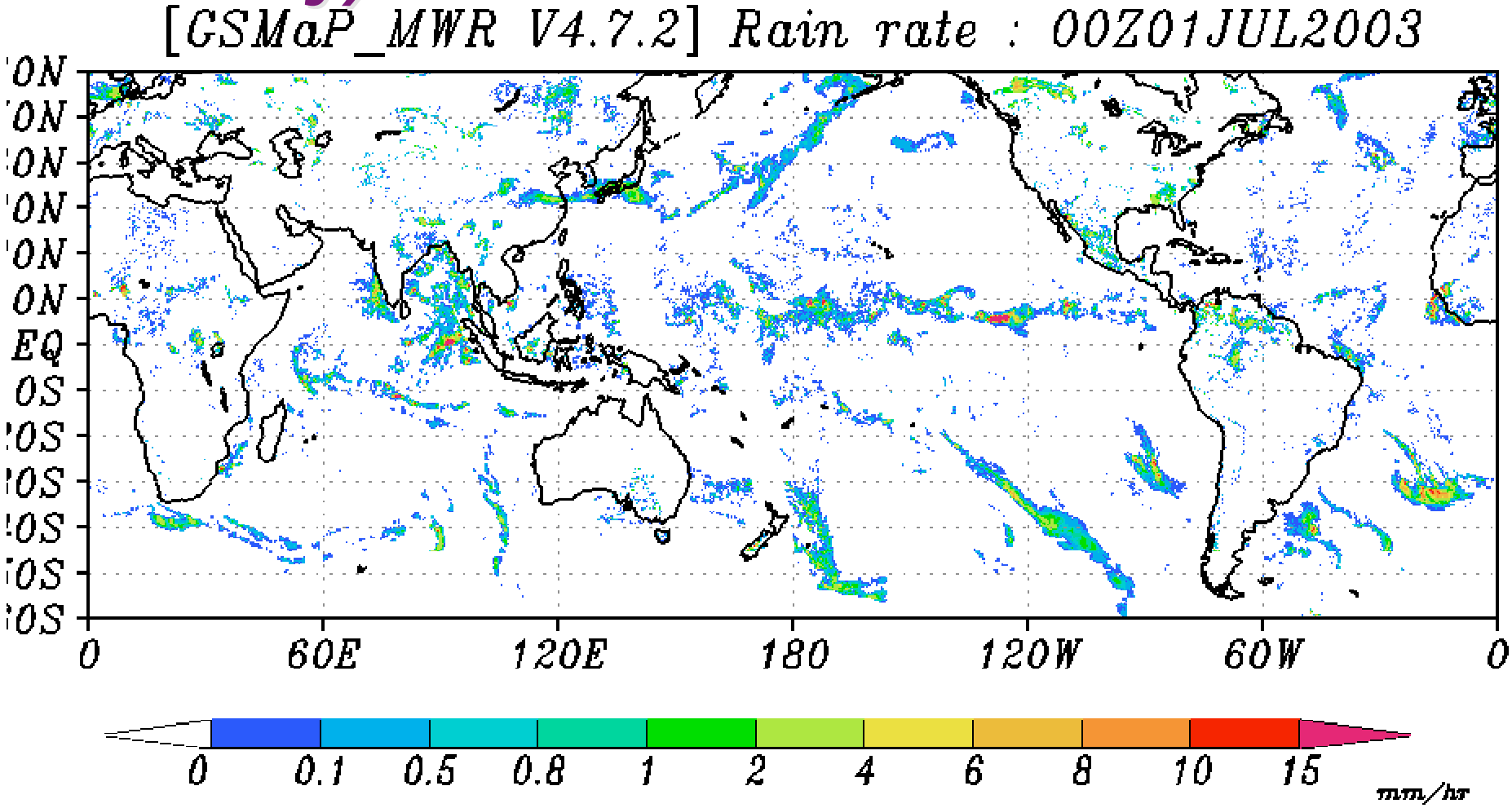
MWR algorithm



Major updates of GSMaP MWR algorithm
(for TMI, AMSR-E, AMSR)

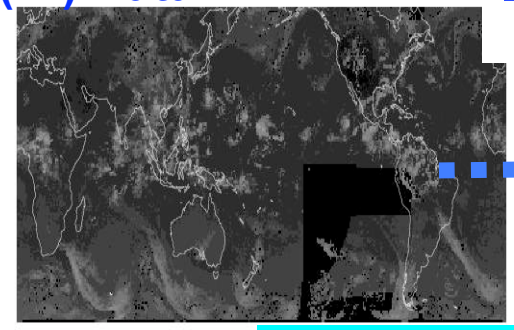
Version	Notes
V2.2	Aonashi's original algorithm
V3.2	**Rain/No-rain classification over land by Seto (Version 1).** This rain/no-rain algorithm utilizes of no-rain 85 GHz TB.
V4.3	**Rain profiles model by Hirose (Version 1).** This model defines 8 different rain types (Land: 5 types, Ocean:3 types), and gives rain profile for each types of rain.
V4.5	Improved rain profiles model (Version 2). Improve rain/no-rain algorithm over land (Version 2).
V4.6	**Improvement of scattering algorithm using PCT85 and PCT37.**
V4.7	**Introduction of melting layer model.** **Improve the "coast algorithm"**
V4.7DSD	**DSD model based on rain type and DSD parameter (_) of TRMM/PR**

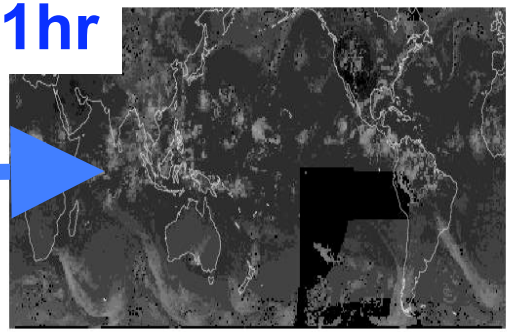
MWR combined product (6 hourly)



MWR+IR combined algorithm
GSMaP_MV algorithm

Infrared (IR) Data





Cloud Motion Vector
(1hr intervals)

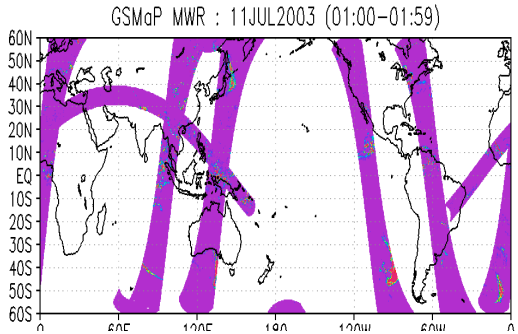
Advection of rain system by Cloud Motion Vector

IR+MWR combined

GSMaP_MV

Global Rain Map @ $T=T_0$

Global Rain Map @ $T=T_0$+1hr

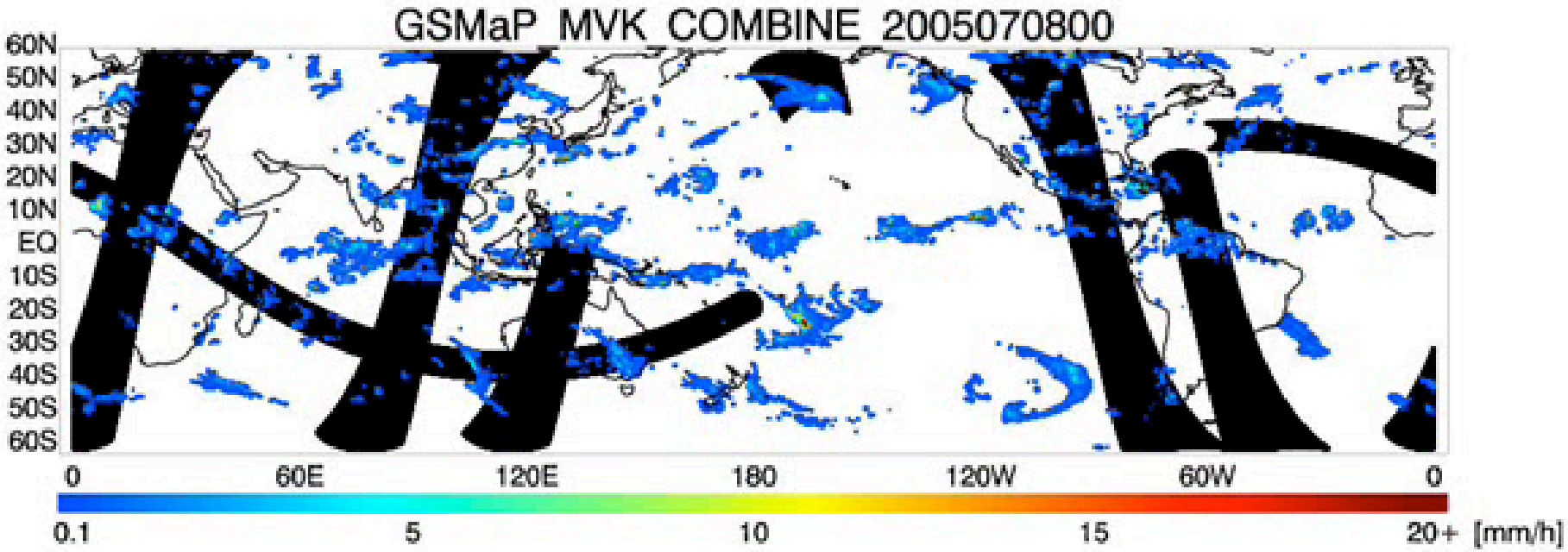


Microwave Radiometer (MWR)

Update the rain map by the latest MWR data

Past 1 hour MWR rain retrievals

Global precipitation map of GSMaP MVK (0.1degs., 1 hour : July 2005)



Status of satellite-borne microwave radiometer data processed by GSMaP algorithm

Table1: Status of each satellite data (MWR algorithm)

Satellite (Sensor)	Processed period	Features
TRMM（TMI）	Jan 1998-Dec 2005	Ver.4.7.2
Aqua（AMSR-E）	Jan 2003-Dec 2005	Ver.4.7.2 (Applicable to the high latitude)
ADEOS-II（AMSR）	Apr 2003-Oct 2003	the same as above
DMSP F13, F14, F15（SSM/I）	Jan 2003-Dec 2005	the same as above

Table2: Grid data products

Spatial resolution	Temporal resolution	Archives	Data source
0.1 degrees	hourly	July 2005	Combined MWR (TMI, AMSR-E, AMSR, SSM/I_3) +IR (Latitude ±60º)
0.25 degrees	Various*	Jan 2003-Dec2005	Combined TMI and AMSR-E (AMSR added from April 2003-October 2003) (Latitude ±60º)
0.25 degrees	daily, monthly	Jan 1998-Dec 2005	TMI (Latitude ±40º)

Various (6hours, 1 day, 1 month)*

Other topics and Future plan

- Retrieval experiment of TB of high frequency channel with non-hydrostatic model for the validation of solid precipitation scheme of cloud resolving model.
- Development of real-time system for MWR-IR combined product @JAXA/EORC.
- We have joined the international PEHRPP (Pilot Evaluation of High Resolution Precipitation Product) group and now we are evaluating various precipitation maps around Japan using Radar-AMeDAS data.

- Further improvement of MWR algorithm (e.g. convective/stratiform classification, characterization of solid precipitation).
- Detailed validation of the products
- Develop a rain retrieval algorithm by combining TRMM/PR and microwave radiometer algorithms.

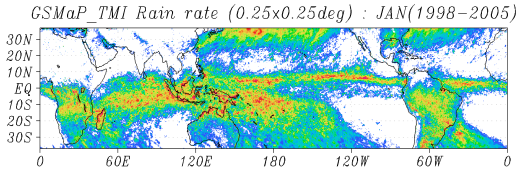
Global Satellite Mapping of Precipitation (GSMaP)

Production of a high-precision, high-resolution global precipitation map using satellite data

Overview

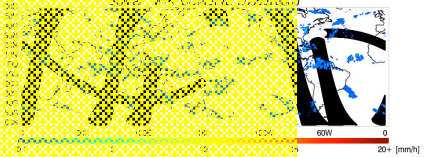
A new project on "The Global Satellite Mapping of Precipitation (GSMaP) " started in 2002 under the sponsorship of Japan Science and Technology Agency. This research aims at developing a microwave radiometer algorithm compatible with a precipitation radar algorithm, and eventually producing global precipitation maps with high-resolutions, for instance, produced with grid spacing of 0.1 degree of latitude by 0.1 degree of longitude, by comprehensively analyzing only satellite data including IR data. There are four principal sub themes of this research in order to attain the goals stated as follows; (1) creation of the global precipitation map, (2) improvement and development of the rainfall rate retrieval algorithms, (3) improvement and development of the physical models of precipitation, (4) routine observation of precipitation by the ground-based radars.

Global precipitation map of GSMaP (TRMM/TMI)



The GSMaP (Global Satellite Mapping of Precipitation) project is promoted for a study "Production of a high-precision, high-resolution global precipitation map using satellite data," under R&D of Hydrological Modeling And Water Resources System sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST).

High resolution map from the MWR-IR combined algorithm (utilization of Cloud Motion Vectors and the Kalman filtering)



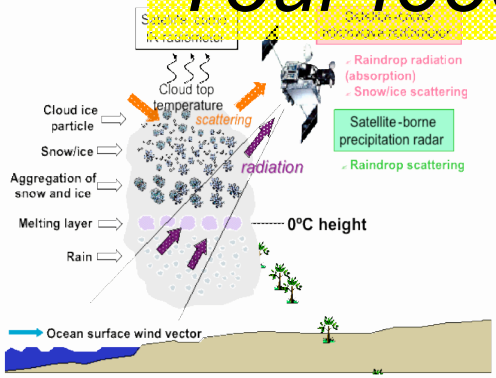
Data DVD (grid data and movies, GSMaP DVD No.2) is released

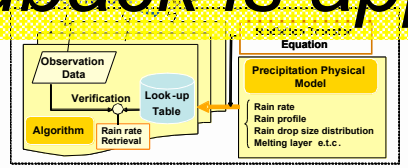
If have not get one, please contact me.

Your feedback is appreciated.

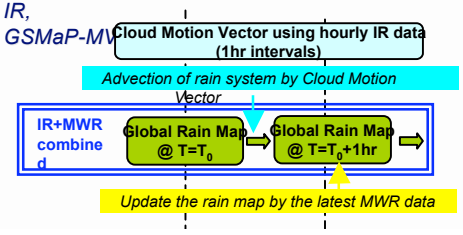
- Production of high precision and high resolution global precipitation map by using satellite-borne microwave radiometers.
  - Retrievals from SSM/I ◊ 3)
  - Utilization of precipitation radar and GEO-IR information
- Development of rainfall retrieval algorithms based upon Active and Passive microwave radiometer algorithms
  - Use of the physical model of precipitation and bright-band model
- Precipitation map production technique for the coming GPM (Global Precipitation Measurement) satellite around 2012

Observation of Precipitation from Space





GSMaP High Resolution Algorithm using Geo-IR, GSMaP-MW



The first version of GSMaP Data DVD (No.1) was released in May, 2006. With version-ups of GSMaP algorithms, GSMaP Data DVD No.2 is released. To read the data you must use computers with DVD-R drives. (Click "start.html" to start viewing.)
This DVD-R provides global rainfall data produced by the GSMaP Project. We wish, if possible, users of the data sets will give feed back to us for our future algorithm improvements.

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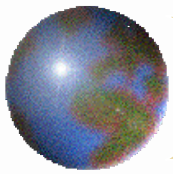


Backup slides

GSMaP Team Members

P. I.
K. Okamoto

Ground Radar Observation Group
K. Iwanami (GL), K. Nakagawa, H. Hanado, Y. Kitamura, Y. Shusse

- *4D data base of cloud physical parameter*
- *Validation of algorithms*

Physical Precipitation Model Group
N. Takahashi (GL), S. Sato, J. Awaka, T. Kozu, Y. Takayabu, M. Hirose

- *Precipitation profile model*
- *Melting layer model*
- *DSD model*

Precipitation Retrieval Algorithm Group
T. Iguchi (GL), K. Okamoto, S. Seto, S. Shimizu, K. Aonashi, H. Eito, T. Inoue

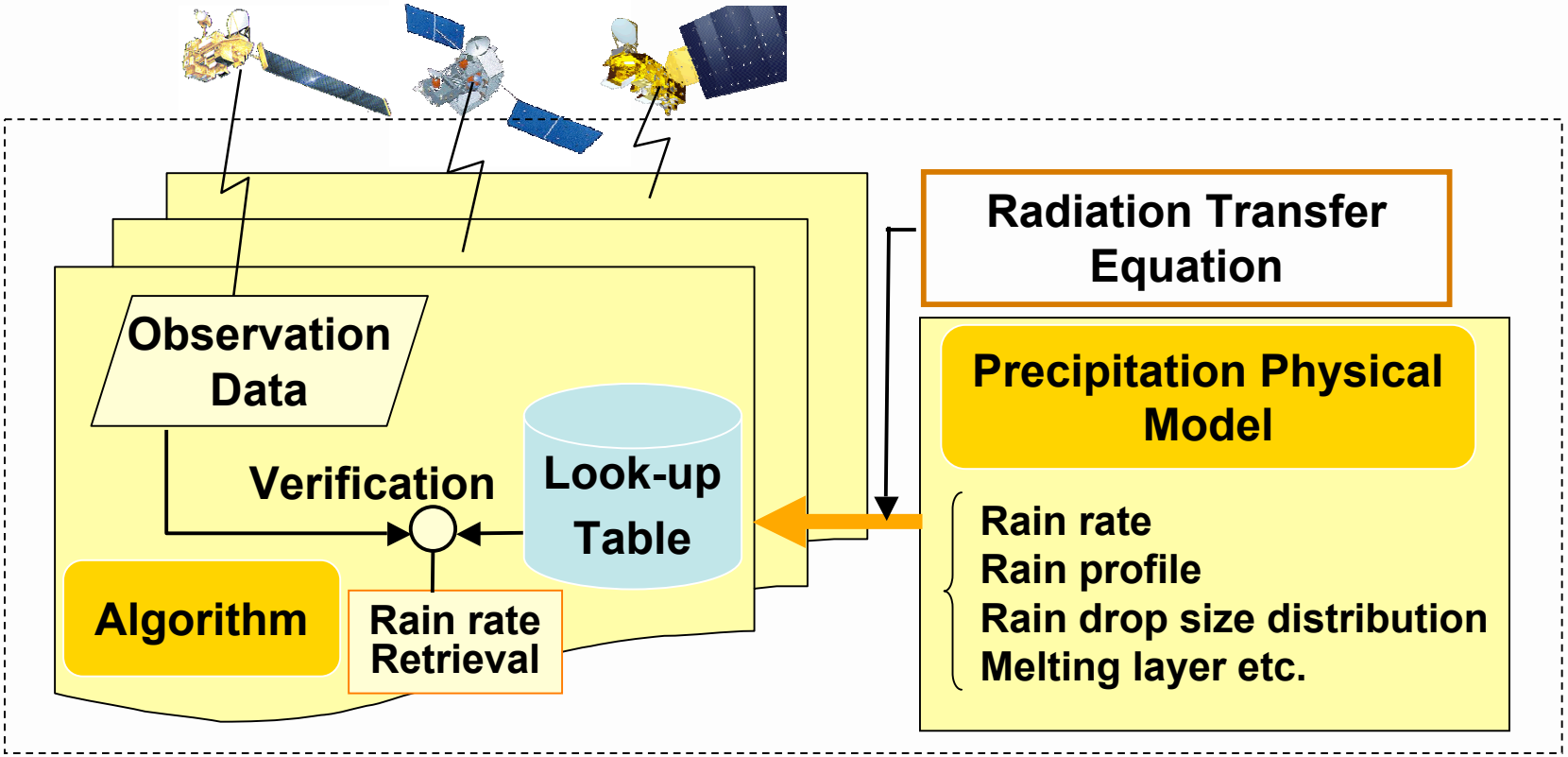
- *Scattering algorithm*
- *Rain/No rain classification*
- *Improvement of CRM*

Global Precipitation Map Group
K. Okamoto (GL), T. Ushio, S. Shige, R. Oki, H. Hashizume, T. Kubota, M. Kachi, Y. Iida

- *Global rain mapping*
- *Evaluation of products*
- *MWR+IR combined algorithm*

* GL: Group Leader

Basis of Rain Rate Retrieval by Microwave Radiometers



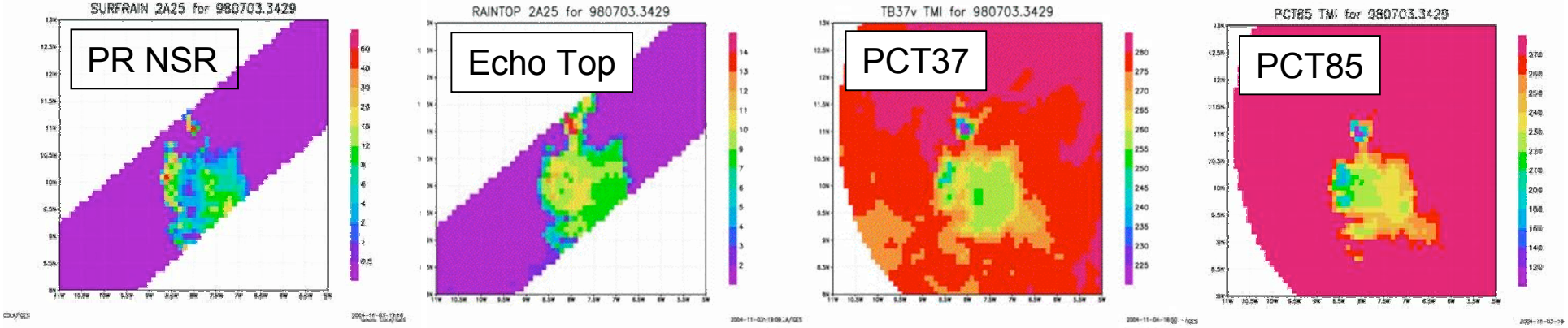
- Satellites observe the brightness temperature, integration of radiation and scattering power.
- The relation between rain rate and brightness temperature is tabulated by assuming precipitation physical model and calculating the radiative transfer equation. The rain rates giving the nearest brightness temperature values to the observed ones are considered to be the most appropriate estimation.

Dual frequency algorithm over land (Aonashi)

V4.6

Motivation

MCS over West Africa 1998.07.03 orbit # 3429



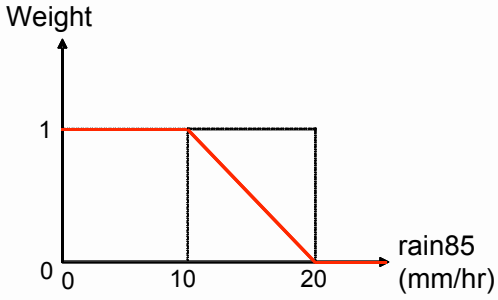
PCT85 (polarization corrected temperature at 85 GHz) is rather similar to the echo top height pattern in PR data, while PCT 37 is similar to PR's NearSurfaceRain (NSR).

This result indicates that the PCT85 represents the temperature near the echo top for deep convective system.

Algorithm --- *Combination of PCT85 and PCT37 instead of using only PCT85 to avoid the saturation in PCT 85*

rainpct3785=
W85×rain85+W37×rainpct37

W85=weight
W37=1−weight



Improvement of Land Algorithm

V3.2

Development of Rain/No Rain Classification Algorithm Using Database

Database of TB under No-Rain condition by using PR and TMI
- 1 x 1 deg. / Monthly
- Gives regression parameter (a, b) and stdev. of the data base (σ_e)

Observation Data TB(85V)

Rain → **Retrieval** → **Rain/No-rain Determination R≧0**

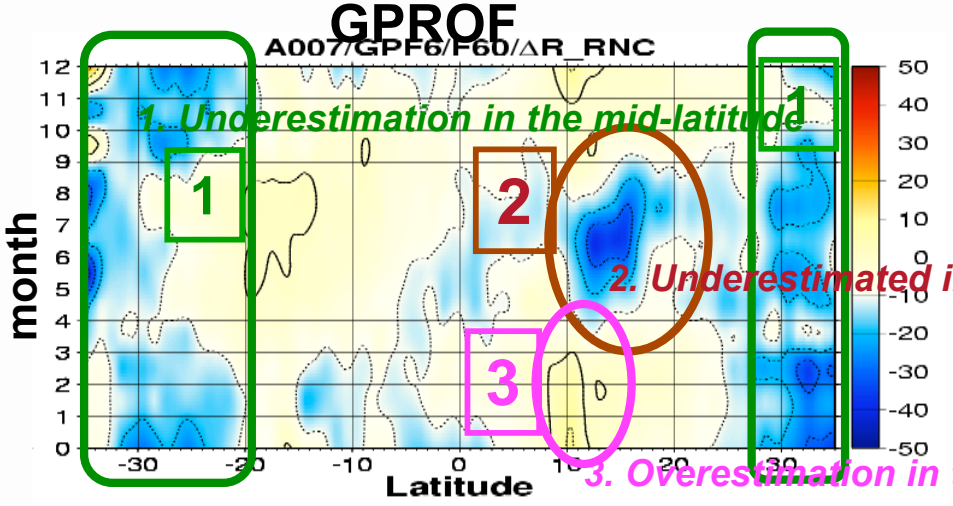
Rain/No-rain Determination
Rain, if $TB_e(85V) - TB(85V) > 0$

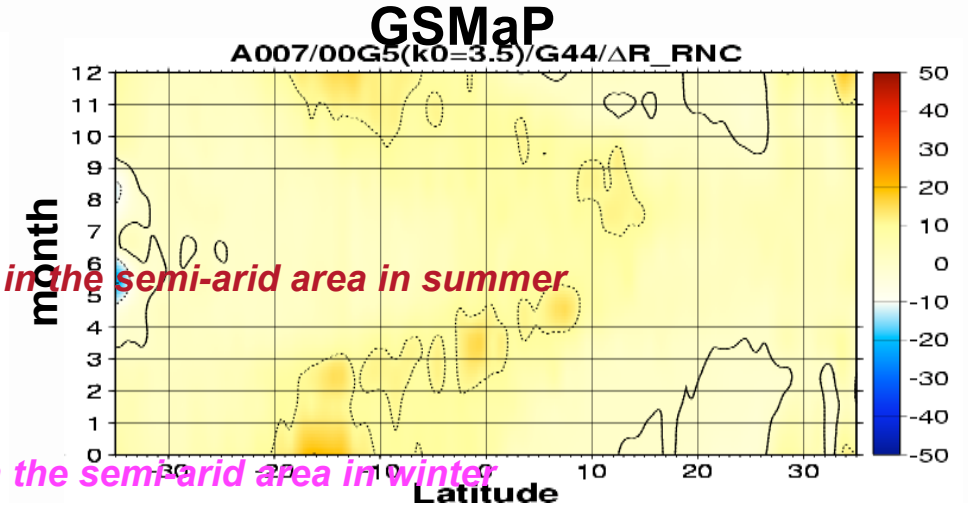
Threshold of No-Rain TB
$TB_e(85V) = a + b \times TB(22V) - k_0 \times \sigma_e$

No-rain → **Rain rate R=0**

Algorithm

Evaluation **Rain estimation error caused by rain/no-rain classification (mm/month)**





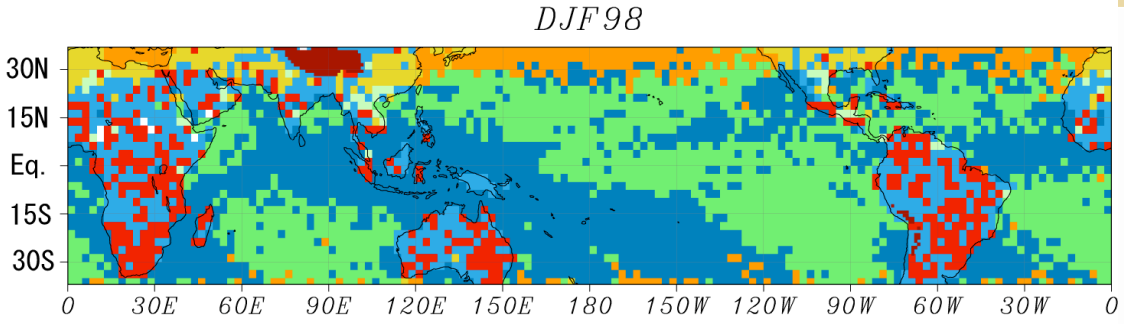
Development of Precipitation Profile Model

V4.3

Classification of Precipitation Type
(Takayabu & Katayama)

Precipitation type database (PR)

2.5º grid
Every 3 months
8 types (ocean:3; land:5)

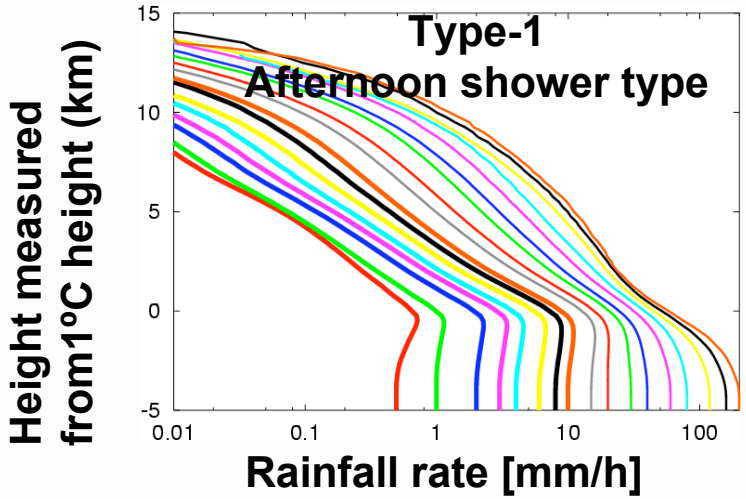


(Land) 1: afternoon shower, 2: shallow rain,
3: Midlat front. systems, 4: organized rain systems,
+ 8: Tibet
(Ocean) 5: shallow rain, 6: Midlat front. Systems,
7: organized rain systems

Precipitation Profile
(Hirose)

Precipitation profile database (PR)

Integrated in each rain type
Prepared for various surface rainfall rate



Rainfall rate profiles classified by rainfall rate (Type-1)
0.5, 1, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 60, 80, 120, 160, 200 mm/h

Melting layer model

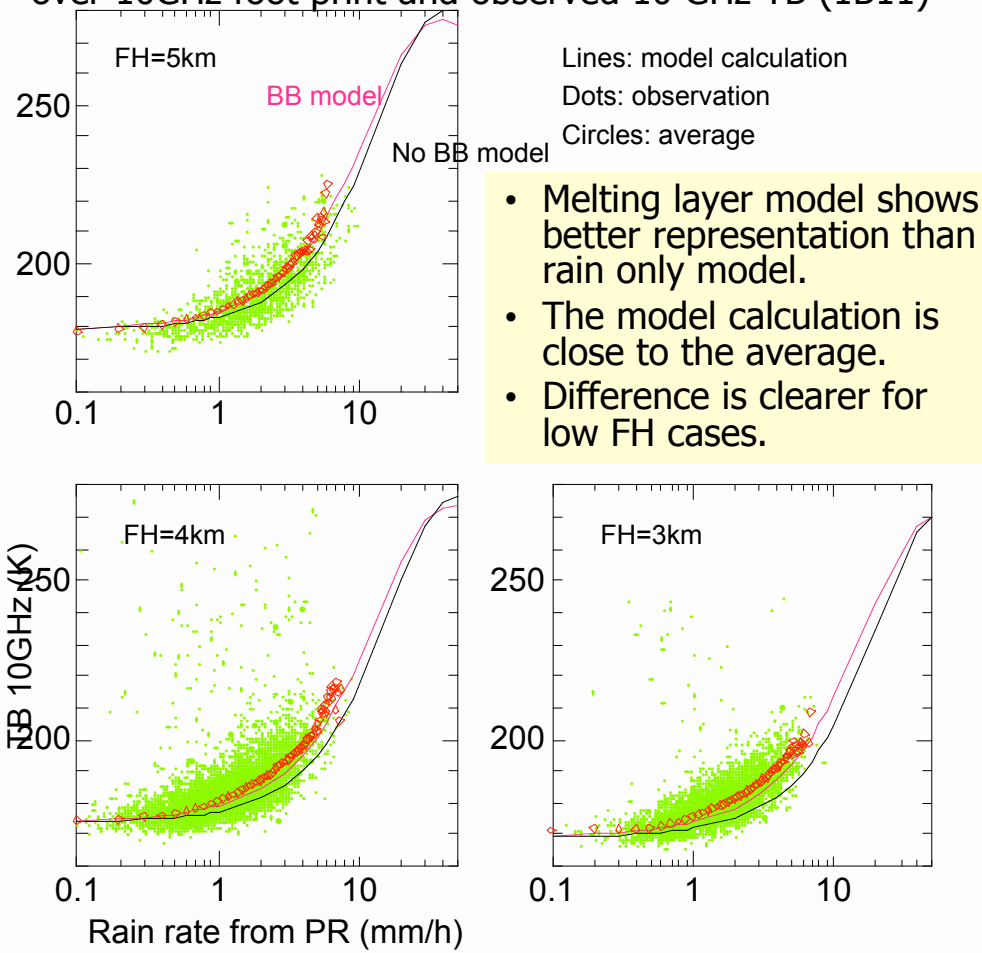
(Takahashi & Awaka)

V4.6BB

Motivation

- To establish the algorithm which has common physical model with PR's algorithm.

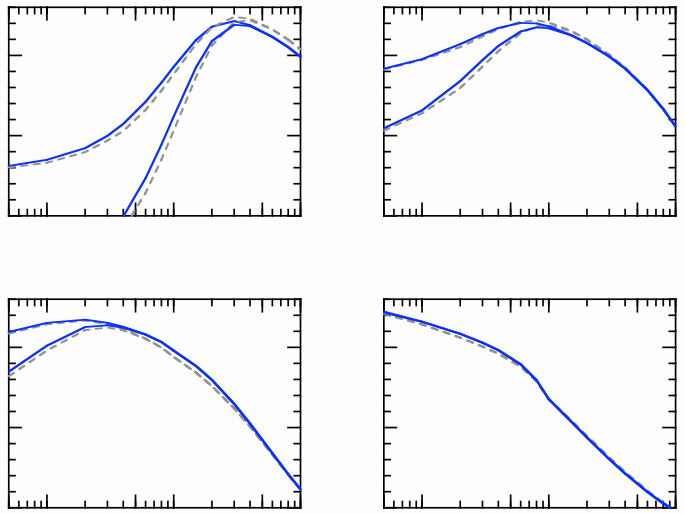
Relationship between PR's rain rate (2A25) averaged over 10GHz foot print and observed 10 GHz TB (1B11)



- Melting layer model shows better representation than rain only model.
- The model calculation is close to the average.
- Difference is clearer for low FH cases.

Melting layer model

- Nishitsuji model which is used for the melting layer model of TRMM/PR is used to create the lookup table.
- Number of layers for radiative transfer calculation increased from 14 to 33, 19 layers are allocated for the melting layer with 50m intervals.

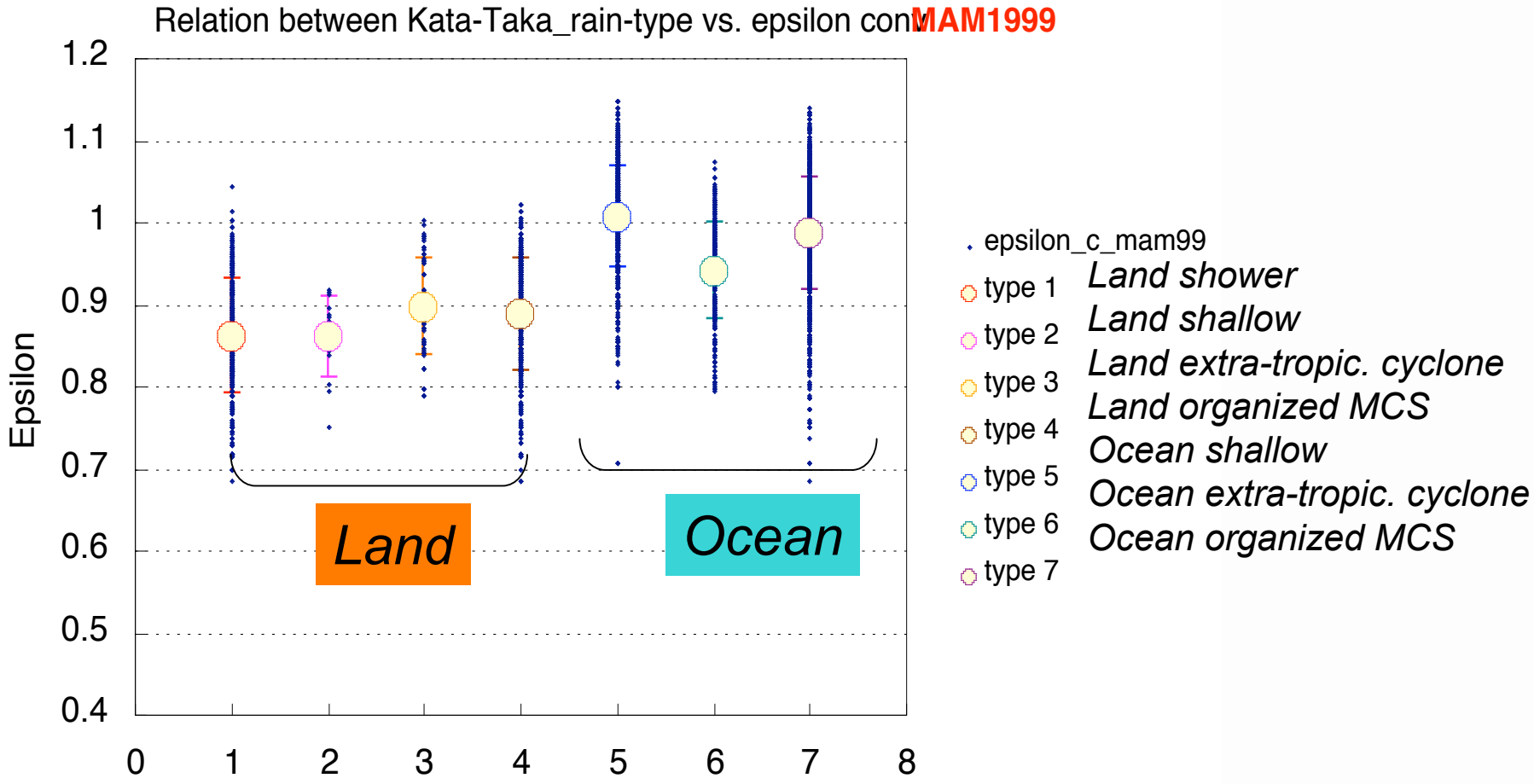


DSD model (Kozu & Takayabu)

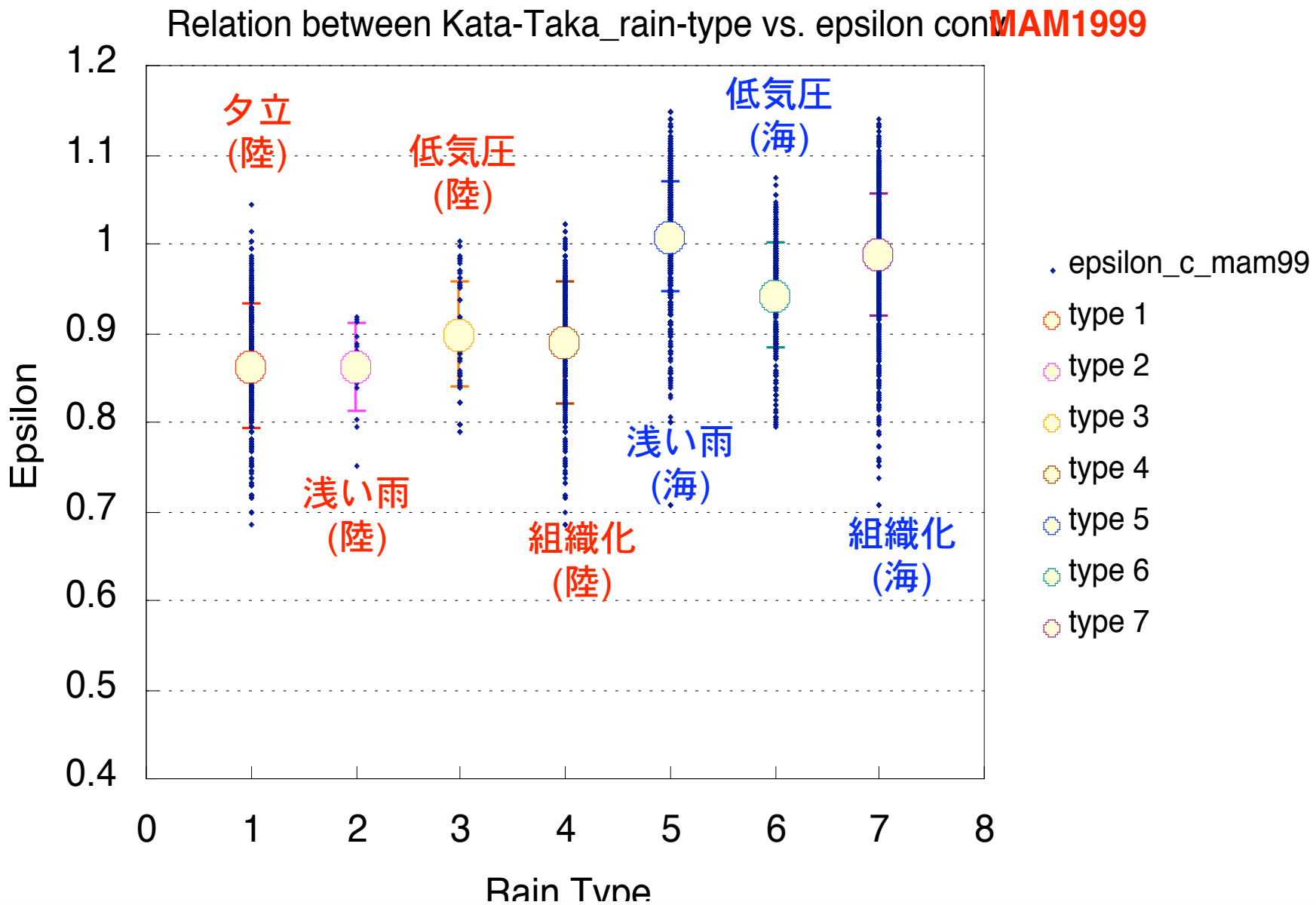
- Use of DSD model parameter from TRMM/PR (_).

$$k = \alpha Z^{\beta}, \quad R = aZ^{b}$$

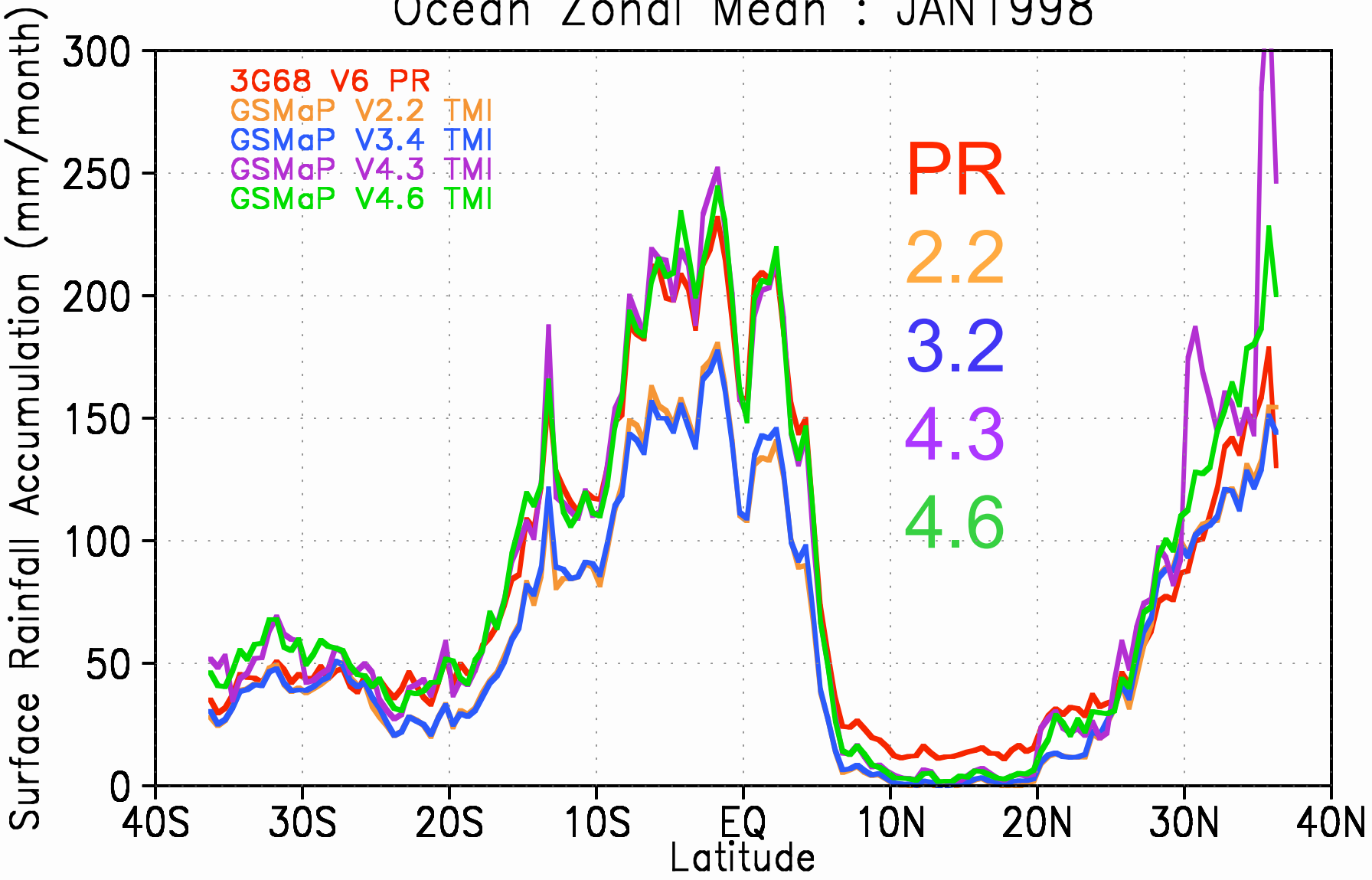
$$\alpha \rightarrow \varepsilon \alpha_{\varepsilon=1}, \quad a \rightarrow \varepsilon^{b/\beta} a_{\varepsilon=1}$$



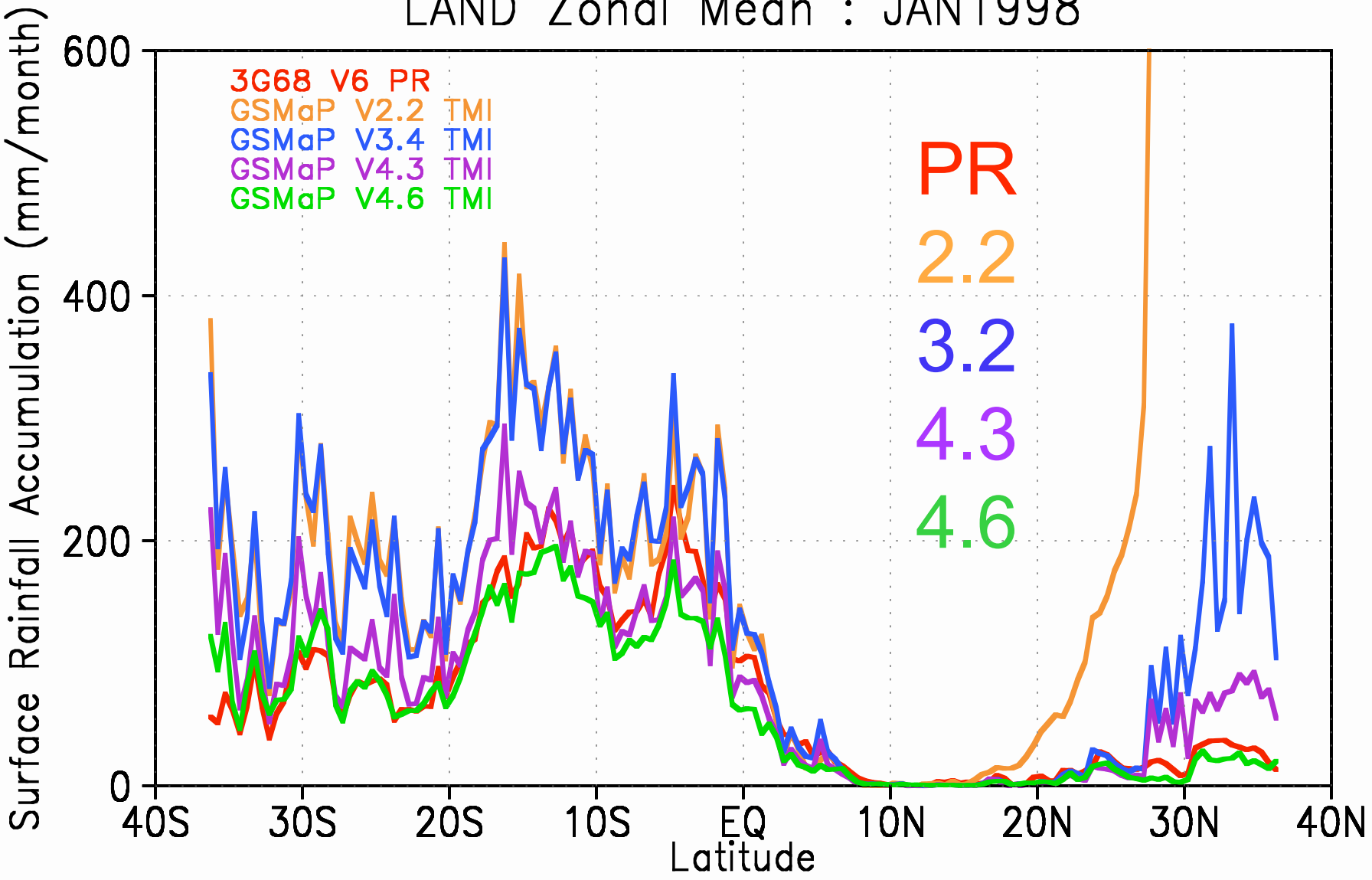
山地・高緯度降雨タイプと対流性



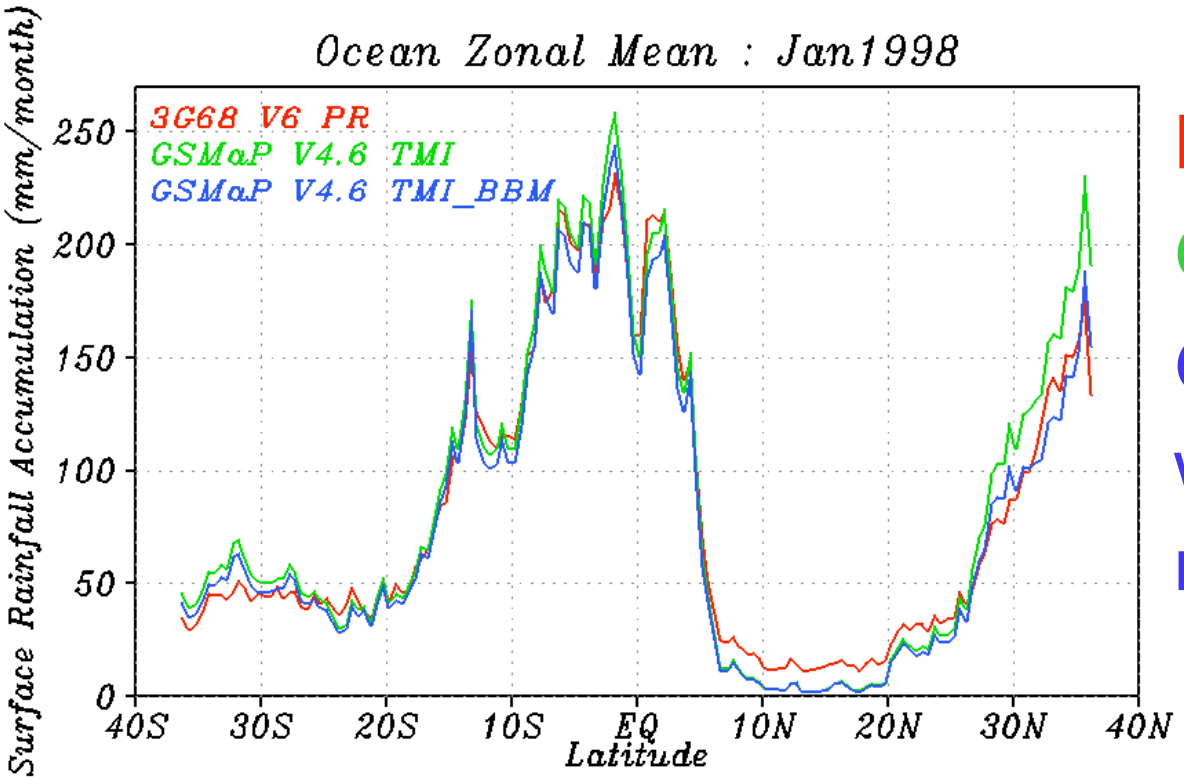
Comparison of Zonal Rain Rate Average (Ocean, January 1998)



Comparison of Zonal Rain Rate Average (Land, January 1998)



Utilization of Melting Layer Model



PR V6

GSMaP V4.6 TMI

GSMaP V4.6 TMI with melting layer model

- Overestimates of the GSMaP over winter mid-latitude oceans are related to too low freezing level heights.
- In experimental results using the algorithm integrated with the melting layer model, the overestimates decreases largely.

Composition of GSMaP Products

TRMM
TMI

Aqua
AMSR-E

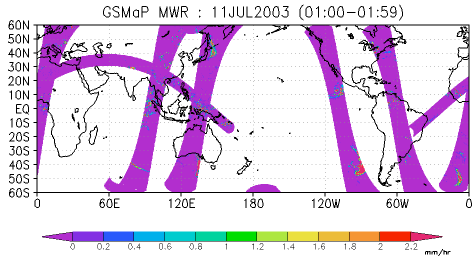
ADEOS-II
AMSR

DMSP
SSM/I

GSMaP
Microwave Radiometer Algorithms

Rain rates retrieved by each satellite microwave radiometer

Geostationary Satellite



1-hour data by TRMM/TMI, Aqua/AMSR-E, ADEOS-II/AMSR, DMSP/SSMI (F13, 14, 15)

Combination

Motion Vector
Kalman filtering

GSMaP MWR

Combined Product
0.5° grid

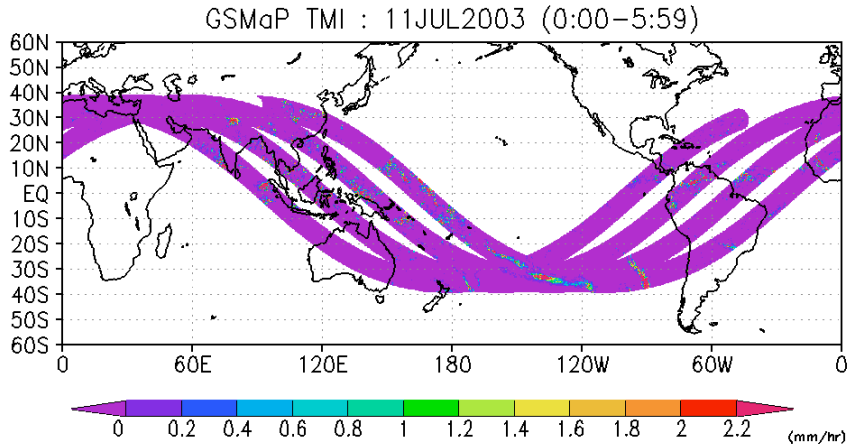
- 30 minutes
- 6 hours
- 1 day
- 1 month

GSMaP MV
GSMaP MVK

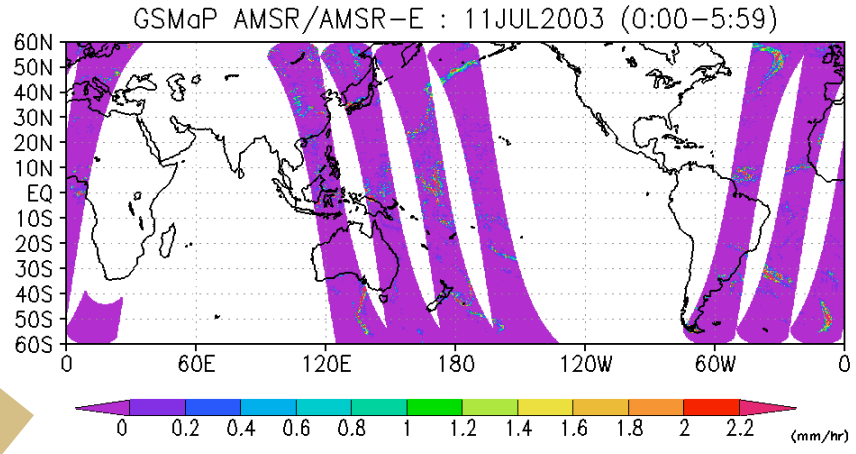
Combined IR/MWR Products
0.1° grid hourly

Example of combined global precipitation map of microwave radiometer data retrieved by TMI, AMSR-E, AMSR and SSM/I (DMSP F13, F14, F15) --- 6 hours

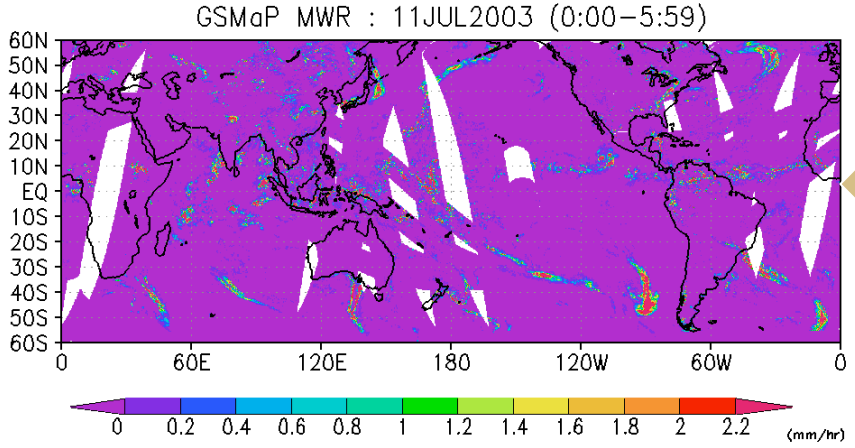
TMI



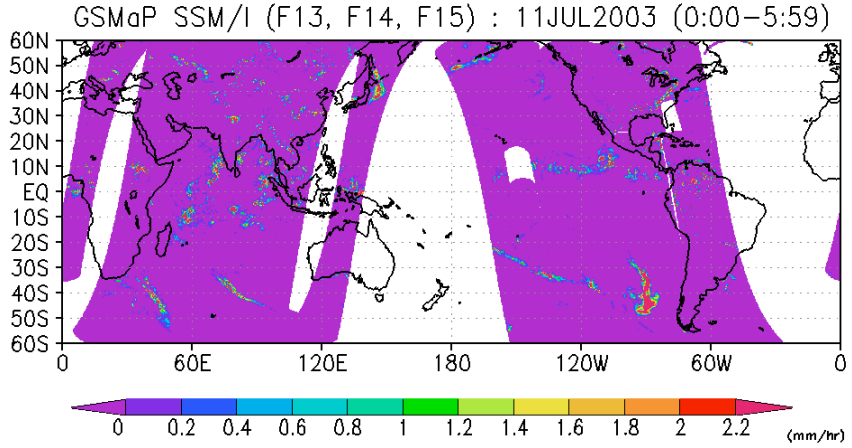
AMSR & AMSR-E



Combined Data (6 hours)



SSM/I （F13, F14, F15）



Major Rain Observation Equipment

10-minute cycle
Volume scanning with 15 elevation angles
＋RHI scanning with 2 or 4 azimuth angles
(Ogimi/Onna)

Temporal resolution: 164s (horizontal and vertical wind)
Height resolution: 100m (1.3μs)

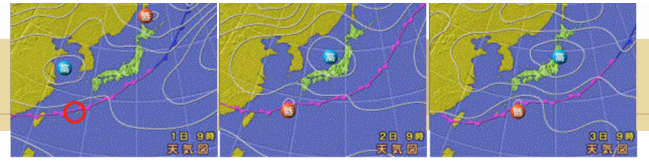
Temporal resolution: 1/3s→60sec average
Height resolution: 50m, continuous observation zenith direction

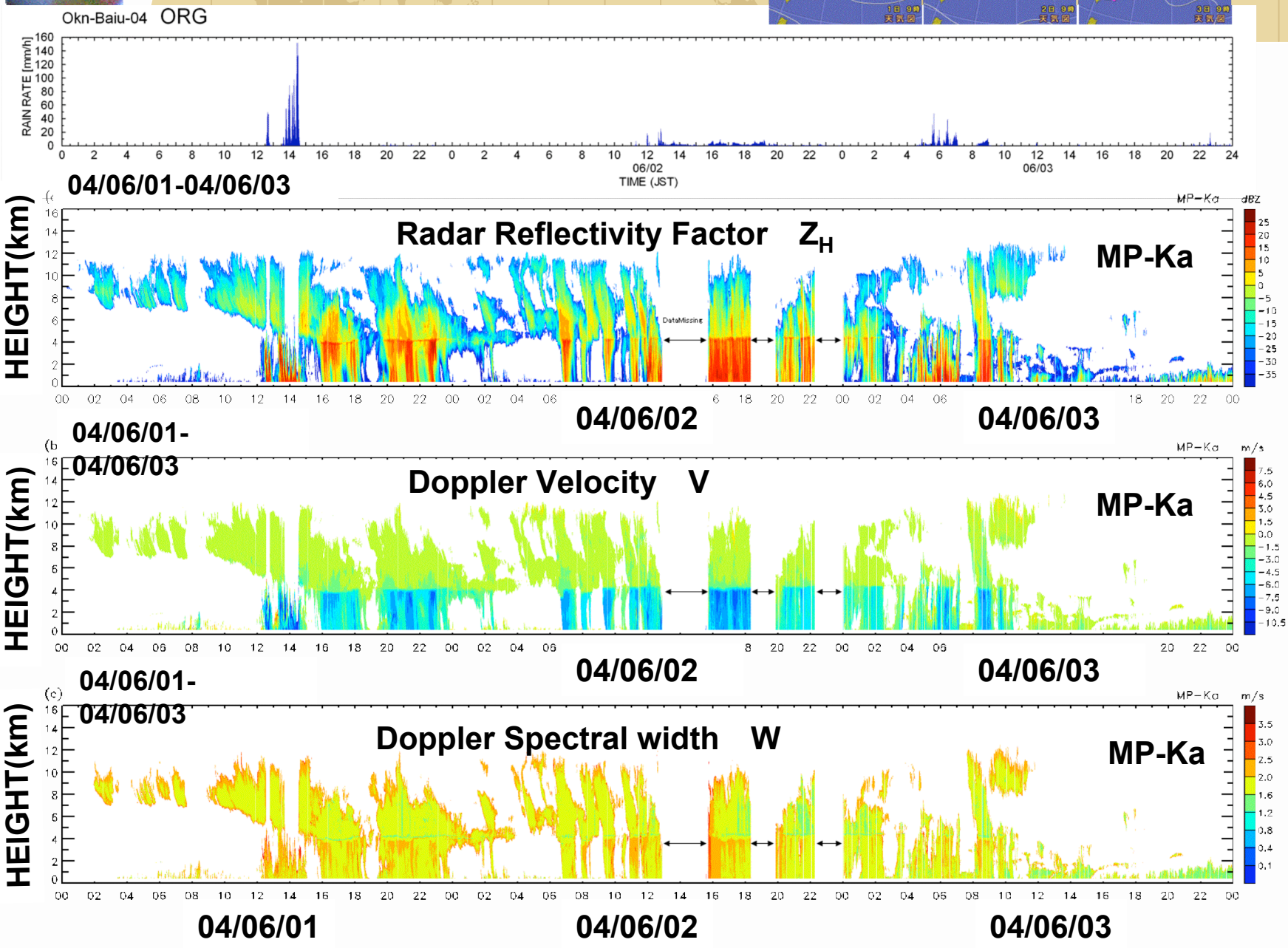
Precipitation Data Set at the Okinawa Baiu Campaign Observation

Okn-Baiu-04 web page = http://www3.nict.go.jp/dk/c218/okn-baiu04/

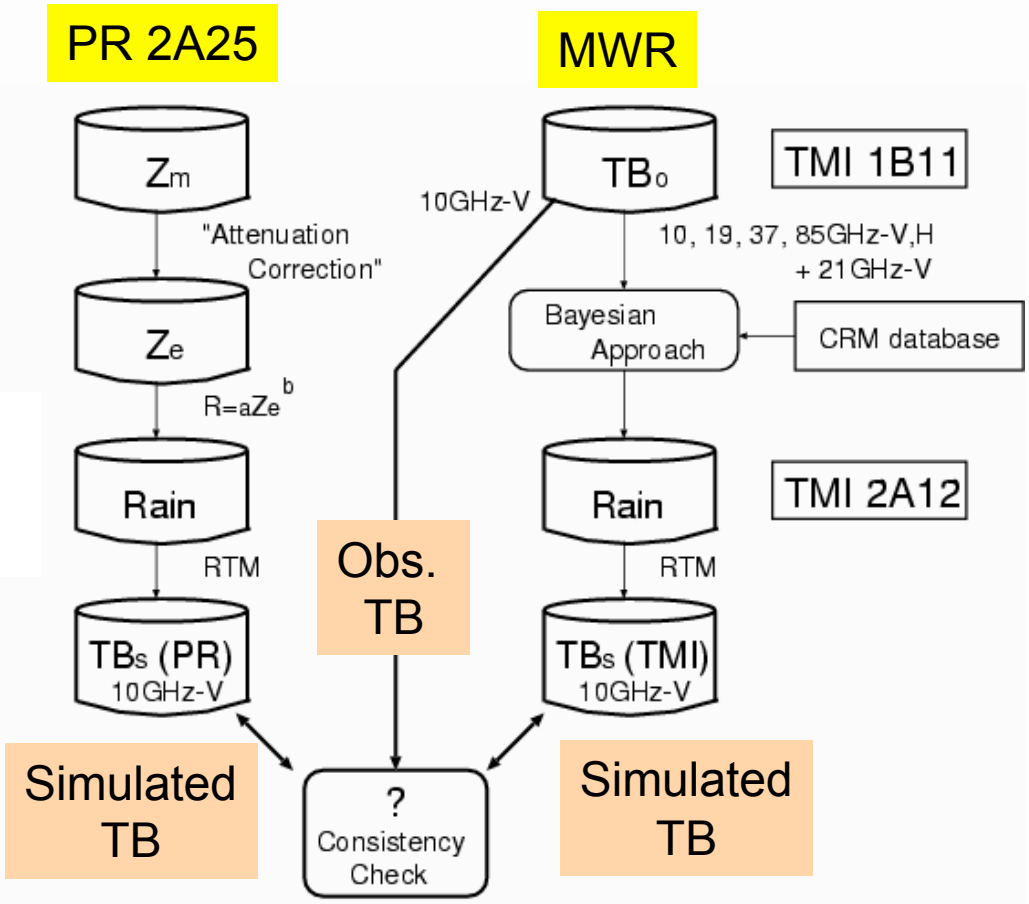
No.	Data/Sensor	Time
1	GPS sonde	UTC
*2	COBRA radar (C-band Doppler Polarimetric Radar)	UTC
3	400MHz WPR (wind profiler)	JST
4	MP-Ka Radar (Ka-band Doppler Radar)	JST
5	MRR (Micro Rain Radar)	JST
6	Microwave Radiometer	JST
7	Ceilometer	JST
8	Meteorological Instruments	JST
9	Optical Rain Gauge	JST
*10	2D Video Disdrometer	JST
11	TRMM/PR(2A25), TMI(2A12), VIRS(1B01)	UTC/JST
*12	AMSR-E	UTC
*13	QSCAT Ocean Wind	UTC
14	AMeDAS	JST
*15	RSM SFC(03-48), 850/700/500hPa(00-51) (numerical weather model)	JST

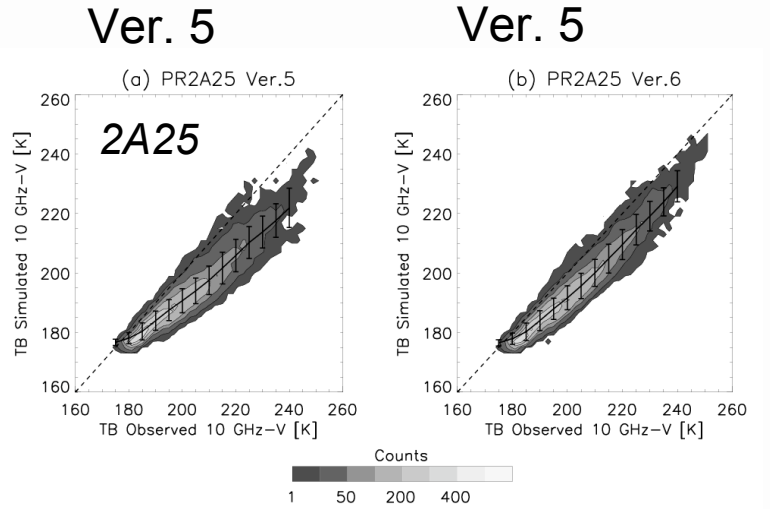
04/06/01-03 (Baiu Rain Front; 93.5mm)

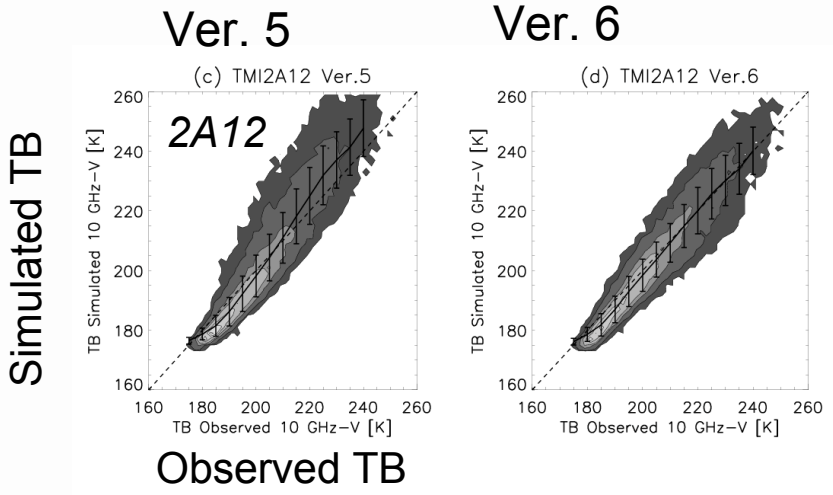




Evaluation of algorithms for TRMM



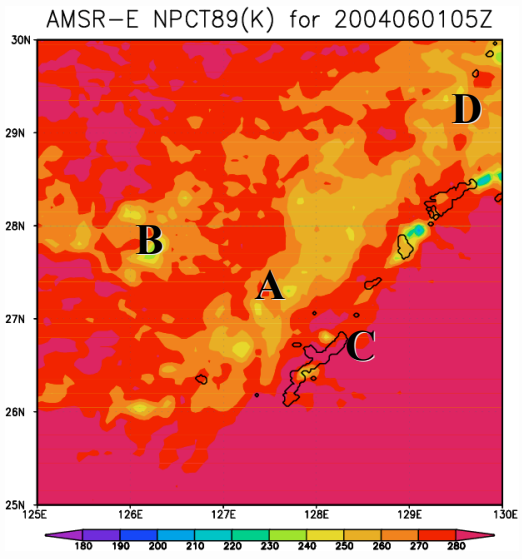


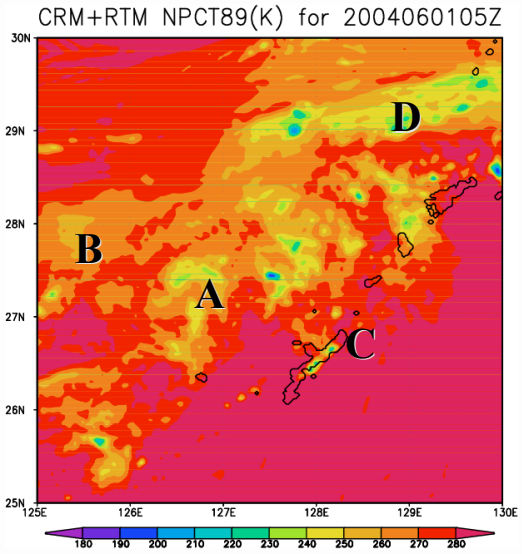


Evaluation of Cloud Resolving Model

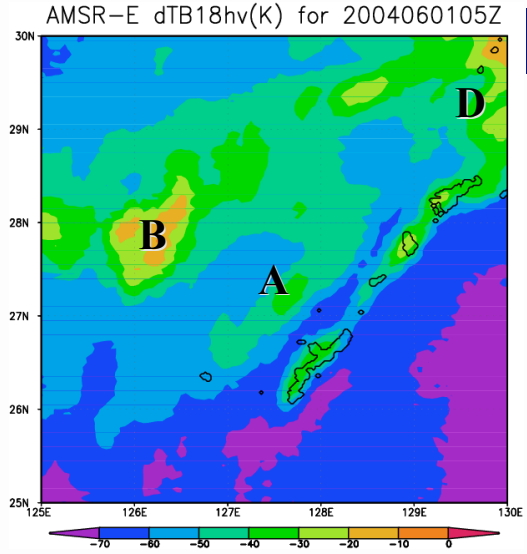
14JST 1 June 2004 (Baiu frontal rainband)

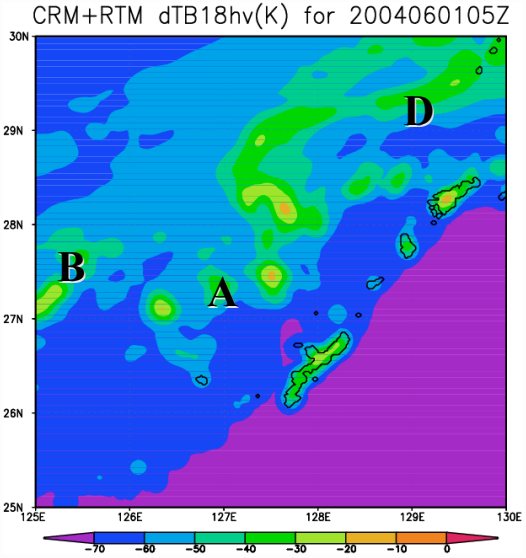
89GHz Scattering INDEX





18GHz Emission INDEX





AMSR-E (Obs.)

Emission Index

Simulation by CRM shows good coincidence with observation indicating that the CRM estimates liquid water properly.

Scattering Index

Simulation shows much larger depression of TB than observation indicating that the to much snow above the freezing height.

2km-CRM & RTM